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TECHNOLOGY UTILIZATION

METALLURGY

A COMPILATION

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Foreword

The National Aeronautics and Space Administration has established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of its research and development, NASA earns for the public an increased return on the investment in aerospace research and development programs.

This publication is part of a series intended to provide such technical information. The 33 items herein reported range widely in the field of metallurgy; they may interest metallurgists and the metals industries, notably persons concerned with the design and fabrication of metallic components and structures.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader's Service Card included in this compilation.

Unless otherwise stated, NASA contemplates no patent action on the technology described.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this compilation.

Ronald J. Philips, *Director*
Technology Utilization Office
National Aeronautics and Space Administration

Contents

SECTION 3. Improvements in Processing

Section 1. Methods of Testing and Detection

NONDESTRUCTIVE DETECTION OF TITANIUM HYDRIDE

With several types of specimens, the following methods of nondestructive detection of titanium hydride were tested comparatively: neutron radiography, ultrasonic attenuation, thermal conductivity, and eddy-current conductivity.

The results with specimens of Ti–6 Al–4 V welded with C.P. weld wire show that neutron radiography is qualitatively useful for detection of localized attack. The difference in density, caused by hydrogen contamination of less than 1000 ppm, probably would not be detectable. The method is expensive (about $300 per exposure) and the nonportable equipment requires a nuclear reactor.

Ultrasonic attenuation seems to show most promise for qualitative and quantitative measurement of hydride formed. Use of frequencies of 10 MHz or higher should reveal levels of contamination lower than 1000 ppm. The commercially available equipment is portable.

The eddy-current-conductivity method is not sensitive to levels of contamination higher than 1000 ppm in alloyed titanium; it is feasible with C.P. (55-A) titanium material or welds, provided dilution is not extensive. The commercially available equipment is inexpensive and portable.

The thermal-conductivity method shows full-scale deflection between hydrided and nonhydrided specimens; it seems useful for detection of levels of contamination lower than 1000 ppm. The commercially available equipment is inexpensive and portable.

Detection is at present only qualitative and confirmed for hydrogen contamination exceeding 1000 ppm. Tests should be extended to lower degrees of contamination and to a range of specimen sizes. A new neutron-radiographic process is reported to be able to detect as little as 100 ppm of hydrogen.

Source: D. J. Hagemaier of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18429)

Circle 1 on Reader's Service Card.

STRESS–CORROSION SUSCEPTIBILITY OF ALUMINUM-7075

Point defects were introduced into specimens of 7075-aluminum alloy by either neutron irradiation or quenching from high temperatures; irradiation was effective at only the highest dosage. The specimens were then tested for stress corrosion during repeated immersions. The initiation and growth of stress-corrosion cracks were monitored continuously by adaptation of conventional ultrasonic apparatus.

The resultant data will be usable eventually for optimization of combinations of strength and resistance to corrosion of aluminum alloys for highly stressed structures. A more immediate benefit may result from use of ultrasonics for prediction of impending catastrophic failure of such structures by stress corrosion.

Source: A. J. Jacobs of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18342)

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RESPONSE OF CAST INCONEL-718 TO HEAT TREATMENT

Differences in Properties of Bars from the Same Heat

Test bar, No.	Aging[a] Temp., °F	Aging[a] Time, hr	Tensile strength, 1000 lb/in² Ultimate	Tensile strength, 1000 lb/in² Yield	Elongation, %	Hardness, Rockwell-C
			RB0170-088 Solution Treatment[b]			
7	1350	6	157.7	140.0	18	38
8	1350	6	160.9	142.6	16	39
5	1350	8	161.6	146.1	13	40
6	1350	8	156.8	143.5	10	40
3	1350	10	161.8	146.7	13	40
9	1350	10	162.7	147.8	13	40
12	1350	10	161.3	145.4	13	40
4	1325	6	139.3	115.7	25	34
2	1325	8	151.7	128.9	23	38
1	1325	10	160.0	140.2	13	39
			AMS-5383 Solution Treatment[c]			
16	1350	6	158.5	135.8	17	38
15	1350	8	157.6	139.7	10	39
14	1350	10	161.3	135.3	13	40
13	1325	6	145.2	119.7	19	35
11	1325	8	151.3	127.8	13	37
10	1325	10	159.1	136.4	13	38

[a]Two-step aging, either 1350° and 1150°F, with holding at each for the indicated time; or 1325° and 1150°F, with holding at each for the indicated time.
[b]2075° ± 25°F for 10 hours; furnace cool to 1900° ± 25°F for 2 hours.
[c]2000° ± 25°F for 1.5 hours; air cool; 1775° + 25°F for 1 hour; air cool.

Apparently minor variations in composition, within specified limits, may result in significant differences in response of Inconel-718 to heat treatment. Specified mechanical properties can be met readily if the aging is correctly matched to the material.

Sixteen test bars from the same heat, homogenized and solution heat treated by one of two methods, were aged at one of two different temperatures for various periods. The great differences in properties that resulted from a proportionately small (25°F) difference in aging temperature (see Table) show that at some point the material is quite sensitive to aging; this point may vary with composition.

Ranges in aging time and temperature must be permitted if the specified properties—especially ductility—are to be attained consistently. Repetition of aging, or of solution heat retreatment and aging, should be permitted. A Rockwell-C hardness of 36 to 38 is suggested as a guide, but not for acceptance of parts. Cleanliness of parts, and absence of moisture during both the solution treatment and aging, are essential.

Source: R. G. Cron of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18502)

Circle 3 on Reader's Service Card.

TITANIUM HYDRIDE DETECTED BY NEUTRON RADIOGRAPHY

Presence of titanium hydride can be detected nondestructively by neutron radiography.

When X-rays interact with the electron rings of an atom, neutrons are absorbed by the atom's nucleus; the absorption rate is independent of atomic number and is a function of the neutron cross section of the material radiographed. Elements such as hydrogen, gadolinium, and boron, have high cross sections and are opaque, while aluminum, titanium, and steel have low cross sections and are relatively transparent. Titanium hydride has a high cross section and is opaque.

The object to be radiographed is exposed to a beam of neutrons emitted by a nuclear reactor. Neutrons pass through the object and, by way of a thin sheet of metallic gadolinium, create an image on X-ray film behind and in contact with the gadolinium. This converter screen of gadolinium captures neutrons and emits low-energy gamma rays to which the film is sensitive.

Source: D. J. Hagemaier of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-14343)

Circle 4 on Reader's Service Card.

TITANIUM CRACKED BY STRESS CORROSION IN METHANOL AND CERTAIN OTHER LIQUIDS

When exposed to methanol, commercially pure titanium (Ti-75A) and two alloys (B-120VCA and Ti–6 Al–4 V) are cracked by stress corrosion at stress levels ≥ 25% of their yield strengths. Titanium fails in the following fluids also: pure nitrogen tetroxide (N_2O_4); methanol mixed with synthetic seawater or other chloride-contaminated water; Freon-MF (whether or not contaminated with chloride); chloride-contaminated isopropanol; and 1:1 mixture of methanol and Freon-MF.

The following cause no failure: N_2O_4 inhibited with either nitric oxide (NO) or water; methanol inhibited with pure water; isopropanol; Freon-TF (whether or not contaminated with chloride); Aerozine-50 (whether or not contaminated with isopropanol); pure water (with or without commercial inhibitors or chloride); trichloroethylene; benzine; chloride-contaminated monomethylhydrazine; chloride-contaminated Stoddard solvent; and ethylene glycol.

Source: R. E. O'Brien and L. E. Ghiggins of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-15697)

No further documentation is available.

HEAT CRACKING OF INCONEL-718 IN ZONES AFFECTED BY WELD HEAT

Inconel-718, a commercial high-strength alloy, has been considered the most weldable of the precipitation-hardened nickel-based alloys. Tungsten–inert gas (TIG), inert gas–metallic arc, and electron-beam welding have all been used, and the resultant Inconel-718 components include the largest commercial forgings available today. The extensive welding associated with these forgings, however, has introduced problems; the physical and mechanical metallurgy of the large mass complicates joining of the material. Although the common problem of such alloys has been cracking during heat treatment after welding, Inconel-718 is subject to heat cracking of the zones affected by weld heat; this cracking appears to result from heat primarily and to be aggravated by large grain size.

For better understanding and for correlation of the weldability (resistance to heat cracking) of Inconel-718 with chemical, mechanical, and metallurgical factors, the alloy was subjected to hot-ductility tests, TIG fillerless-fusion tests,

and patch-weld restraint tests. Many heats of Inconel-718 were tested, from several mills and in various sizes and configurations. Experiences with welding problems in the shop were compared with results of laboratory tests. Correlation was attempted of the test results with composition, heat-treatment condition, grain size, and microstructure. "Weldable" and "poorly weldable" Inconel-718 were compared. The results gave these indications:

1. High-temperature ductility varies not only from heat to heat but also with variation in the mill processing of any one heat.

2. Inconel-718 is subject to microcracking of the zone affected by weld heat; incidence and severity are directly related to the permanent impairment, of the original elevated-temperature ductility, caused by exposure to a thermal cycle involving a degrading peak temperature.

3. The microcracking of the zone affected by weld heat is associated with formation of low-temperature-melting intergranular films as a result of exposure to temperatures ranging from 2100° to 2200°F.

4. Proper processing in the mill can minimize the undesirable effects of these grain-boundary films, principally through control of grain size and secondary-phase morphology.

5. Laboratory tests of hot ductility and fillerless fusion both proved suitable for measurement of the weld-fabrication characteristics of Inconel-718 mill products; the hot-ductility test is preferred.

6. The data from weld-circle-patch testing were insufficient for evaluation of this test for weldability.

The test procedures employed can be used in determination of the relation between the chemical and thermomechanical history of a weld and the presence of microfissures in it.

Source: E. G. Thompson of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18211)

Circle 5 on Reader's Service Card.

EFFECTS OF HYDROGEN ON METALS

Methods have long been sought for minimizing failures in storage tanks and associated hardware caused by the effects of high-pressure hydrogen, formation of hydrides in titanium, and absorption of hydrogen during various metals-processing techniques. As yet no general solution has emerged, but much experience in the field and many series of tests have led to development of several rules to guide choice of materials and of methods of welding, electroplating, heat treatment, and other processing.

The problem is complicated by the existence of various possible sources (and combinations of sources) of hydrogen. Large quantities of hydrogen may reduce ductility in a metal; accumulations in localized areas may cause internal bursts or blisters. In some circumstances hydrogen reacts with the metal or alloy phases to form brittle compounds resulting in brittle fractures under stresses far below normal.

The hydrides may result from the storage of high-pressure hydrogen, imperfections in the surfaces of metals, use of incorrect weld fillers, inappropriate methods of welding, cleaning, pickling, electroplating, or heat treatment, or original choice of susceptible materials; or from the synergistic effect of two or more of these factors. Clearly some steels are more susceptible than others during fabrication and service. Alpha titanium differs from beta titanium in absorption of hydrogen; use of commercially pure filler wire for welding of Ti–6 Al–4 V alloy tends to formation of more hydride than does Ti–6 Al–4 V filler.

When high-pressure hydrogen is present, entry into the metal is possible when molecular hydrogen is dissociated into atomic hydrogen by catalytic reaction with fresh metallic surfaces. Atomic hydrogen may be formed by the localized energy released by microcracking or in slippage in the metal; it enters the lattice of the metal, and such entry is strongly influenced by temperature and lattice defects and by metals in the process of transformation or under stress. Such conditions provide the energy necessary for the endothermic process of dissolution of the hydrogen into the metal, either as interstitial solid solution or as

metal-hydrogen compounds on the basis of ionic bonding.

Regarding the difference in solubility of hydrogen between alpha and beta titanium, the commercially pure alpha alloy has no stabilizing elements such as the aluminum in Ti–6 Al–4 V. Aluminum belongs to a group of metals (such as Fe, Cu, Ni, and Mo) in which the hydrogen is endothermically formed and dissolved as interstitial solid solution; while titanium belongs to another group (such as Zr, Ta, and Cb) in which hydrogen occurs in the form of positively charged ions. Conditions causing migration of hydrogen and formation of titanium hydride have not been completely defined, although it is generally accepted that Ti–6 Al–4 V alloy has sufficient aluminum to provide adequate solubility of hydrogen, and that the small amounts of hydrides formed are inconsequential. Migration mechanisms have been postulated and studied under various influencing conditions, but the triggering circumstances are far from being defined for confident prediction of limiting compositions of alloys, or for design of weld-filler alloys to control such mechanisms.

Regardless of the basic mechanism or mechanisms of metal-hydrogen reaction, applications must be cautious. The resistance of one alloy to damage by hydrogen under one set of conditions may not apply under another. Special care is needed where welds are used; new alloys and alloy phases may be formed in weldments that are sensitive to hydrogen; and weldments may entrap pockets or narrow bands of hydrogen concentrations that are not readily detectable and from which hydrogen may diffuse even at relatively low temperatures, so that deterioration becomes time dependent.

Every known method of electroplating produces some degree of hydrogen embrittlement of certain alloys, such as the high-strength steel alloys; chromium plating proved to be the most embrittling in a broad evaluation of methods.

Different alloys seem to differ widely in tolerance of hydrogen without failure. Distribution of hydrogen within a sample is a more important factor in hydrogen embrittlement than is average content of hydrogen.

Source: C. E. Cataldo
Marshall Space Flight Center
(MFS-20364)

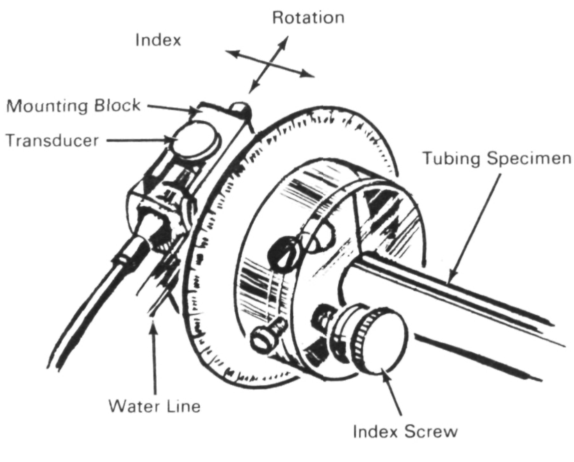
Circle 6 on Reader's Service Card

NONDESTRUCTIVE TESTING OF WELDS IN THIN-WALLED TUBING

A special ultrasonic search unit, or transducer assembly, has been developed for reliable inspection of the quality of melt-through welds in fusion-welded tubing couplers for hydraulic lines. This unit is used in conjunction with high-resolution ultrasonic equipment for inspection of welded assemblies of tubing having diameters of from 0.25 to 1.0 in. and wall thicknesses of from 0.028 to 0.095 in.

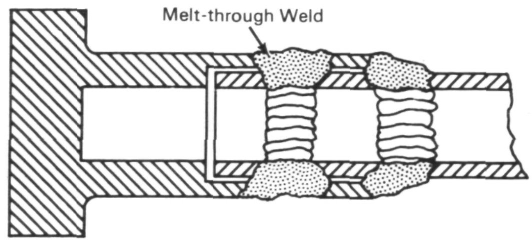
The device consists of a 7/16-in. diam by 1/2-in.-long ultrasonic (25 MHz) transducer contained in a mounting block having a water-line connector; a nonrotatable ("clamshell") plastic housing with index screw and pointer; and a rotatable clamshell, search-unit housing with circular protractor scale.

In preparation for inspection of a tubing specimen, the search unit housing is placed in position over the adapter side of the weld. The nonrotatable plastic housing is firmly mounted on the tube's outer wall by two setscrews, while the transducer is placed in its mounting block and secured by a setscrew. The mounting block with the transducer is then arranged in the guide of the rotatable housing. The ultrasonic medium, water, is fed into the mounting block beneath the face of the trans-



ducer. Signal traces are observed on the oscilloscope, and the mounting block is moved normal to the tubing axis until the ultrasonic response is optimum. The mounting block is then secured by a setscrew in the guide of the rotatable housing.

For an inspection, the transducer assembly (in the rotatable housing) is rotated (circumferentially) about the weld while ultrasonic response is observed on the oscilloscope at 10-deg intervals. Weld-quality signal traces recorded on the oscilloscope indicate any of the following melt-through-weld conditions: no penetration, partial penetration, full penetration, and excessively rough outer surface. When the 36 circumferential readings are completed, the index screw is rotated one-half turn to index the transducer assembly 0.020 in. axially along the weld. The circumferential scanning procedure is then continued at this axial position and successive 0.020-in. increments until the entire weld is covered. The quality of the weld is evaluated from the point-by-point oscillograms.



This instrumentation can also detect (1) faulty braze bonds in thin-walled, small-diameter joints; and (2) the wall thickness of thin-walled metal tubing.

Source: D. J. Hagemaier of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
and G. J. Posakony
subcontractor to
North American Rockwell Corp.
(MFS-18144)

Circle 7 on Reader's Service Card

STRAIN-AGE CRACKING IN RENE'-41

A reliable weldability test has been developed for investigation of strain-age cracking in batches of Rene'-41. The test has been used in determination of the effects of material and process variables, and for demonstrating effective and practical means for reducing the extent of cracking.

Two welding studies consisted of tensile, impact, and stress-rupture tests; as far as possible the same material was used in both so that the results could be compared directly. The following variables in materials and processing were considered: solution-annealing time, temperature, and number of cycles; cooling rate; aging temperature; and carbon content. The alloy's ductility and toughness were of primary interest. Variations from normal processing that either impaired or enhanced durability were noted.

The resistance of each batch of Rene'-41 to strain-age cracking may now be determined before its introduction into the manufacturing process; batches may be evaluated with a controlled-heating-rate tensile test or a weld-circle-patch test. Low ductility in high-temperature air is the main contributor to strain-age cracking; batches yielding less than 2% elongation are unsatisfactory. Carbon-poor batches (less than 0.06%) show poor weldability, ductility, and toughness after aging; at 1400°F their ductility averages two-thirds that of normal material.

With rapid cooling (at up to 45°F/min) before aging, the alloy's toughness and ductility are improved over a wide range of elevated temperatures.

Resistance to strain-age cracking as well as the critical mechanical properties of toughness and ductility are improved by modifying the size, type, and distribution of the grain-boundary carbide particles and of the γ' precipitate. Modification is accomplished by preweld heat treatment, and postweld annealing under an inert atmosphere.

A promising subject for further investigation is the relation between the type of heat-treatment atmosphere and the amount of strain-age cracking.

Source: E. G. Thompson and Martin Prager of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18650)

Circle 8 on Reader's Service Card

DETECTION OF HYDROGEN-CONTAINING CONTAMINANTS ON METALLIC SURFACES

A spark-emission-spectroscopy technique, developed for analysis of surface contamination of metals, is readily applicable for control of the quality of surface preparations; also it is useful in fundamental investigations of surface properties of metals.

Porosity is by far the most common defect in welds of aluminum alloys, and hydrogen is definitely its direct cause. The greater solubility of hydrogen in molten than in solid aluminum, and the resultant precipitation (in the form of hydrogen bubbles) on solidification, have been identified as the mechanism behind this porosity.

Since a "good" weld demands a surface relatively free of absorbed hydrogenous contaminants, their concentration must be measured by quantitative surface analysis. It has been found that surface absorbants can be ionized by high-voltage sparks; for use of this technique, a special sparking chamber was assembled, with supporting instrumentation.

With this chamber, one can measure background conditions and sample surface without disrupting the equilibrium of the system; it has a brass baseplate and cover and a borosilicate-glass cylinder for walls. A rotating stage carries the sample and the lower electrode, the upper electrode being supported by the top cover. A pair of standard electrodes provide for internal calibration. Carrier gas is injected through a diffusion plate into the chamber. Supporting hardware includes a liquid-N_2 trap in the carrier-gas line, and controls for chamber pressure and rate of gas flow.

Standard operating procedure consists of a 20-min purge of the system with a 95:5 mixture of He and Ar, a 1-min preblank sparking between the calibration electrodes, a 5-min purge during which the specimen is positioned below the upper electrode, a 1-min sparking of the specimen, another 5-min purge, and a final gas calibration. Spectrographic plates are exposed during each sparking cycle, and the recorded emission structure is analyzed by conventional densitometric procedures.

Source: E. L. Grove, W. A. Losele,
and Z. P. Saperstein of
IIT Research Institute
under contract to
Marshall Space Flight Center
(MFS-20456)

Circle 9 on Reader's Service Card

RADIOGRAPHIC THRESHOLD-DETECTION LEVELS OF WELD DEFECTS IN ALUMINUM

A test program used in the design and fabrication of special, graduated, aluminum penetrameters has been reported. The program was also used to evaluate the threshold-detection capabilities of a fixed radiographic technique in detecting surface and subsurface cracks in welds in 0.25-in. 2014-T651 aluminum.

Tapered slits of predetermined dimensions were selected to simulate aligned weld cracks by bonding the penetrameters to the center line of the weld of a matched set of weld test plates. Penetrameter thicknesses of 0.000, 0.002, 0.003, 0.004, and 0.005 in. were used to simulate crack depth. Equally thin hole-type penetrameters, containing eight holes with diameters varying between 8T and 0.2T, were also prepared to determine the smallest hole image resolvable under the fixed radiographic technique. Test variables evaluated included hole and slit depths between 0.001 and 0.005 in., the location of the penetrameter within the test plates, and X-ray beam angles of 0, 5, 10, 15, and 20 degrees.

A total of 80 radiographs were taken, the same radiographic technique, equipment, and materials being employed in all cases. The radiographic films were evaluated by five highly competent film interpreters, and the threshold-detection capabilities of the fixed radiographic

technique were defined and compared in terms based on relations between minimum detectable width, depth, and length of the slits and the maximum radiographic sensitivities achieved for the graduated hole penetrameters.

Source: R. W. Tryon of General Dynamics Corp. under contract to Marshall Space Flight Center (MFS-20487)

Circle 10 on Reader's Service Card.

Section 2. Properties and Descriptions of Metals

STRESS-STRAIN DIAGRAMS FOR CERTAIN METALS AT WORKING TEMPERATURES

Materials Tested at Various Temperatures—(x)

Metal			Temperature, °F						
Base	Alloy, type	Condition	70	1200	1300	1400	1500	1600	1800
Nickel	Inconel-625	Annealed	x		x	x	x		x
Nickel	Inconel-718	Aged	x	x		x			
Nickel	Inconel X-750	Aged	x						
Nickel	Hastelloy-C	Annealed	x					x	
Nickel	René-41	Aged	x			x			
Iron	17-4 PH	H-900	x						
Iron	Maraging 250	Annealed	x						
Iron	HY-80	Q & T	x						
Iron	C-1030	Normalized	x						
Aluminum	99.5% pure	Annealed	x						
Aluminum	1100-0		x						
Aluminum	6061	T6	x						
Copper	Commercial	As received	x						
Titanium	75a	Annealed	x						

Stress-strain diagrams are presented for various structural metals at certain of their working temperatures; they cover both elastic and plastic regions. Materials and temperatures are listed in the Table.

The basic data represent engineering stress versus linear strain; they do not take into account the reduction in cross-sectional area of a specimen, or the instantaneous change in the gage length. Because the data were obtained mainly in the plastic ranges, they should not be used for approximation of the elastic modulus (Young's modulus) of any material.

Each testing machine was equipped with a load-strain recorder and extensometers capable of measuring linear strain of from 4 to 20% in a 1-in. gage length. Below the proportional limit, the strain rate was maintained between 0.003 and 0.007 in. in^{-1} min^{-1}; when the 0.2% offset yield strength was reached, the rate was increased to

between 0.03 and 0.07 in. in^{-1} min^{-1} and held there during loading in the plastic range of a specimen. After collection of the load-strain data the loads were converted to engineering stresses, and the resultant stress-strain relations were plotted.

Source: G. L. Heslington and S. D. Foster of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18388)

Circle 11 on Reader's Service Card

SPEEDS OF RESPONSE TO AGE HARDENING OF FIVE NICKEL-IRON ALLOYS

Table 1. Hardness after Aging in Salt at 1400°F for Various Times

Alloy	Solution-annealing temp., °F	Hardness (Rockwell-C) after aging for						
		0 sec	10 sec	100 sec	1000 sec	1 hour	8 hours	16 hours
Inconel-718	1950	8	21	23	30	34	39	42
Inconel X-750	1800	20	32	34	37	39	39	37
René-41	1975	18	30	31	31	35	38	45
René-62	1975	20	33	35	39	40	45	47
CG-27	1875	6	24	29	30	35	40	42

Table 2. Specified Annealing, Age Hardening, and Hardness

Alloy	Solution-annealing temp., °F	Age hardening		Hardness Rockwell-C
		Temp., °F	Hours	
Inconel-718	1950	1400 – 1200	20	36 – 45
Inconel X-750	1800	1300	10	32 – 38
René-41	1975	1400	16	≥ 32
René-62	1975	1400	16	≥ 32
CG-27	1875	1450	16	39 – 41

Speeds of response to age hardening are reported (Table 1) for Inconel-718, Inconel X-750, René-41, René-62, and CG-27; the data are important for evaluation of the cracking tendencies of welded assemblies during heat treatment after welding.

After parallel-surface grinding, the samples (0.75-in.-thick slices from 0.75-in. bars, or 0.75-in. cubes) were solution annealed under argon for 1 hour and then quenched in water; they were then age hardened in salt at 1400° ± 10°F for 10 sec, 100 sec, 1000 sec, 1 hour, 8 hours, or 16 hours before quenching in water. The samples reached the 1400°F in 6 min 55 sec. Rockwell hardness was measured before and after age hardening.

The four alloys other than Inconel X-750 hardened with time beyond 1 hour at 1400°F, their normal age-hardening temperature which is 100°F higher than Inconel X-750's normal temperature (Table 2). After 16 hours the hardness of Inconel X-750 dropped slightly because of overaging.

Source: E. F. Green of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18285)

Circle 12 on Reader's Service Card

IMPROVED MAGNETIC PROPERTIES FOR FERRITIC STAINLESS STEELS

For use in lightweight, fast-acting, propellant valves, which require high-permeability stainless steels having low coercive forces, ferritic stainless steels can be improved by softening and by cleansing of the structure.

For thin-walled (roughly < 0.050-in.) components such as those in small, solenoid-actuated, propellant valves, softening and cleansing are possible in one operation: annealing in hydrogen at > 2000°F. The high diffusivities of the impurities in the ferritic structure permit rapid reduction in carbon and nitrogen contents, and improvements in the attendant magnetic properties. For 430-grade stainless steel, coercive forces may be reduced below 1 Oersted, while maximum permeability may exceed 5000.

Typical treatment entails annealing for 2 to 4 hours at 2050°F under dry hydrogen, rapid furnace cooling to 1525°F, and then slow cooling to room temperature. The time at temperature depends on the size of the component and on the starting material. Desirably, the carbon content is reduced below 0.01%.

Source: Martin Prager of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MSC-15917)

No further documentation is available.

IMPROVED HIGH-TEMPERATURE MECHANICAL PROPERTIES FOR RENÉ-41

Slow cooling at between 40° and 20°F/min, between solution annealing and aging (16 hours at 1400°F), greatly improves the ductility of René-41 at high temperatures while smoothing earlier variations in properties that reflected sensitivity to cooling rate and to variations in carbon content. Strength levels, are reduced only slightly, remaining above minimum requirements. The concomitant reduction in resistance to stress rupture at very high levels of stress is not normally a problem. The structure's resistance to intergranular stress oxidation may be improved.

These lower cooling rates increase toughness also; toughness and ductility are usually improved by roughly 50%. The normal more rapid cooling (150° to 75°F/min) tends to yield very low toughness as determined from precracked Charpy-impact specimens.

Source: Martin Prager of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18173)

Circle 13 on Reader's Service Card

REDUCTION OF RESIDUAL THERMAL STRESSES IN MASSIVE CASTINGS

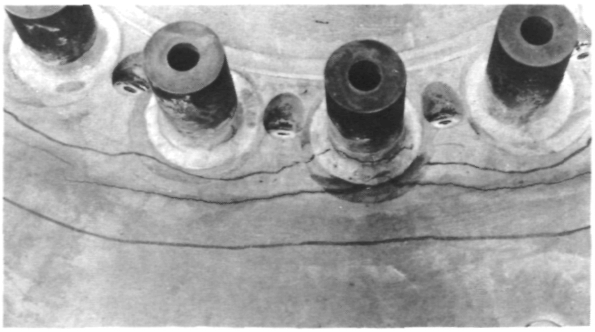


Figure 1. Crackes Dome

While undergoing heat treatment, massive castings or metallic assemblies, nonuniform in wall thickness, may develop internal stresses because of uncontrolled and uneven cooling; such stresses may lead to subsequent failure. For example, a dome made of Inconel X-750 cracked extensively during 16-hour aging at 1300°F (Fig. 1); the rupture was traced to stresses developed during uncontrolled cooling in the course of prior thermal treatment.

Such residual stresses can be reduced by use of

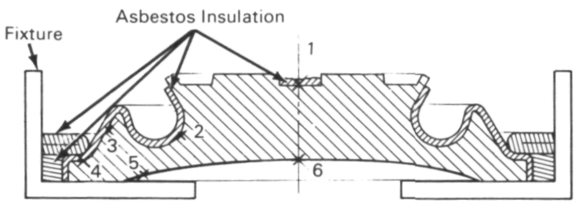


Figure 2. Section of a Cast Dome; Cracks Suffered without Insulation are Numbered.

asbestos insulation to slow the cooling of the thinner sections (Fig. 2).

Source: G. A. King of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-12332)

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BETTER LOW-TEMPERATURE MECHANICAL PROPERTIES FOR CAST INCONEL-718

Properties at 70°F of Investment-Cast Inconel-718 after Various Heat Treatments

Specimen		Heat treatment						Tensile Strength 1000 lb/in^2		
		1st Temp.			2nd Temp.			Yield 0.2% offset	Ultimate	Elongation in 1 in., %
No.	Type[a]	°F	Hours	Cooling	°F	Hours	Cooling			
10[b]	M	2000	4	Argon				100.5	126.6	19.5
48[b]	A	2000	4	Argon				107.7	127.1	6.0
14	M	2050	10	Argon				114.3	124.2	8.0
54	A	2050	10	Argon				140.1	147.4	7.5
16	M	2050	10	Furnace	1900	2	Argon	106.2	121.6	9.0
56	A	2050	10	Furnace	1900	2	Argon	140.0	146.6	8.0
15	M	2050	10	Furnace	1850	2	Argon	114.1	122.3	22.0
55	A	2050	10	Furnace	1850	2	Argon	143.7	151.5	10.0
20	M	2100	10	Argon					140.9	12.0
60	A	2100	10	Argon				139.4	151.5	9.0
19	M	2100	10	Furnace	1900	2	Argon	135.2	140.9	12.0
59	A	2100	10	Furnace	1900	2	Argon	139.3	155.5	20.0
17	M	2100	10	Argon	1875	2	Argon	125.7	131.4	4.5
57	A	2100	10	Argon	1875	2	Argon	139.8	144.5	2.0
18	M	2100	10	Furnace	1850	2	Argon	136.0	143.6	16.0
58	A	2100	10	Furnace	1850	2	Argon	135.6	145.2	15.5

[a]M, heat 27V1272 air-cast by Misco; A, heat 27V3361 vacuum-cast by Austenal.
[b]Aged 8 hours at 1400°F; furnace-cooled to 1200°F; total aging time, 20 hours. All other specimens aged according to para. 1 of text.

The following procedures for heat treatment and aging give the best combination of strength and ductility of Inconel-718 at low temperatures. Homogenization: hold at 2075° ± 25°F for 10 hours; furnace cool to 1900°F for 2 hours; cool to 70°F under argon. Aging: hold at 1350°F for 10 hours; furnace cool to 1150°F; hold for total aging time of 20 hours. Melting begins at 2150°F and so limits the homogenization temperature to 2100°F. Better casting practices are needed to decrease segregation and increase the internal soundness of castings.

When cast material is homogenized at temperatures above 1950°F, a grain-boundary precipitate

forms during the subsequent aging cycle; thus it must be conditioned at 1900°F before the aging cycle. It is believed that, during the furnace cooling between the two homogenization temperatures, the second homogenization part of the cycle promotes retention of the Lave's phase in solution and restricts formation of grain-boundary films during the subsequent aging.

The Table compares mechanical properties at 70°F of material receiving single or double homogenization, the aging procedure for all but two specimens being that described in paragraph 1; the low elongation of specimens 17 and 57 is attributed to the cooling to 70°F under argon before the second homogenization at 1875°F.

Source: E. F. Cook of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-90756)

Circle 15 on Reader's Service Card

RENE'41: REDUCTION OF STRAIN-AGE CRACKING

Experimentation shows that preweld heat treatment and postweld annealing under an inert atmosphere effectively reduce the extent of strain-age cracking in Rene'-41. Rapid ($\leq$ 45°F/min) postweld heating and reduction in weld energy are less successful.

Low ductility in air at high temperatures is the principal contributor to such cracking. Ductility varies significantly from heat to heat; heats having less than 2% elongation seem to be unsatisfactory. The resistance to cracking of each heat may now be determined, before introduction of the heat into the manufacturing system, with a controlled-heating-rate tensile test and a weld circle-patch test.

The latter test satisfactorily evaluates several process variables when multiple (four or five) samples are used and procedures are fully automated. The specimen design and the automatic test procedure developed during this study are economical and simple enough to permit multiplicity of tests.

The carbon-poor ($<$ 0.06%) heats of Rene'-41 evaluated showed the poorest weldability and low ductility and toughness after aging; ductilities at 1400°F were typically 33% less than those of normal material. Slowing of the cooling rate to 40° or 20°F/min after the solution annealing (before aging) is a simple way to improve toughness at all temperatures, and ductility over a wide range of high temperatures. Stress-rupture life under very high loading ($>$ 90,000 lb/in^2) may be reduced by as much as 50%, but this weakness is insignificant in many applications. With such lower cooling rates, elongation exceeded 30% at 1400°F. Ductility was minimal at about 1150°F but was highest (about 14% elongation) with the low cooling rates; these values are about 20% higher than those now attained.

Ambient-temperature properties were good and relatively insensitive to variations in heat treatment: typical were tensile strength of 130,000 (yield) and 200,000 lb/in^2 (ultimate), and 20% elongation; precracked impact strength varied from 500 to 100C in.-lb/in^2. Resistance to strain-age cracking and the critical mechanical properties of toughness and ductility can be improved by modification of the size, type, and distribution of the grain-boundary carbide particles by heat treatment. The influence of the heat-treatment atmosphere on the extent of strain-age cracking is a most significant area for further investigation, as well as a factor in determination of fundamental mechanisms of strain-age cracking.

Source: M. Prager and E. G. Thompson of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-14269)

Circle 16 on Reader's Service Card.

PROPERTIES OF OFHC COPPER AND ITS LITHIUM AND CHROMIUM ALLOYS

Presented in graphs and tables are (1) tensile data on annealed, oxygen-free, high-conductivity (OFHC) copper at temperatures from 70° to 1900°F (Table 1); (2) the specific heat of OFHC copper throughout a similar range: and (3) comparative thermal-conductivity data on annealed OFHC copper, lithium-copper (Lydox), and chromium-copper (spec. MIL-C-19311) at temperatures from 400° to 1600°F (Table 2).

The OFHC copper bars tested for tensile strength at 1400°F and above were chrome plated for prevention of excessive oxidation which was significant at 1900°F despite the plating. Addition of lithium or chromium increases the strength of copper; after heat treatment and aging, the tensile strengths of chromium-copper may attain 42,000 (yield) and 55,000 lb/in^2 (ultimate).

Source: A. Townhill of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18582)

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Table 1. Tensile Data on Annealed OFHC Copper

Bar, No.	Test temp., °F	Tensile strength, 1000 lb/in. Ultimate	Yield, 0.2% Offset	Elongation in 2 in., %
1	70	31.4		57.0
2	70	29.4		61.5
3	70	29.7		53.0
4	200	28.2		
5	200	28.0	18.7	39.7
6	200	28.4	19.7	45.8
7	400	23.1	12.4	50.0
8	400	23.2	18.6	44.0
9	400	23.4	12.8	50.3
10	600	19.3	16.6	15.4
11	600	17.1	11.4	25.8
12	600	18.0	10.5	27.9
13	800	15.0	13.0	20.2
14	800	13.6	10.3	19.0
15	1000	8.3	5.9	48.6
16	1000	8.5	5.4	47.5
17	1200	4.6	1.50	44.5
18	1200	4.6	1.51	53.3
19	1300	3.5	1.26	45.3
20	1300	3.3	1.21	46.0
21	1400	2.88		45.6
22	1400	2.82		44.3
23	1500	2.19		44.4
24	1500	2.24		47.1
25	1600	1.74		25.2
26	1600	1.58		49.8
27	1700	1.30		40.7
28	1700	1.40		34.8
29	1800	0.99		54.1
30	1800	0.99		47.3
31	1900	0.66		55.0

Table 2. Thermal Conductivities of Copper and Two Alloys

Temp., °F	Conductivity, Btu $ft^{-2}in^{-1}$ $°F^{-1}hr^{-1}$		
	OFHC copper	Lithium-copper	Chromium-copper
400	2600-2650	2290-2340	1930-1980
600	2520-2590	2220-2270	1860-1920
800	2470-2520	2160-2220	1800-1850
1000	2370-2460	2090-2140	1720-1790
1200	2350-2420	2040-2090	1680-1740
1400	2310-2400	1980-2050	1610-1680
1600	2270-2360	1910-2000	1530-1620

THERMAL-EXPANSION PROPERTIES OF AEROSPACE MATERIALS

The thermal-expansion properties of materials used in aerospace systems have been reported in a single handbook. The data, presented in charts and tables, are arranged in two sections: one covers cryogenic temperatures down to −423°F; the other, elevated temperatures to 2000°F (or as applicable).

The data derive from experimental measurements, supplemented by information from various sources in the literature. Test procedures and equipment are described, and analyses of the measurements are included.

Source: E. F. Green of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18335)

Circle 18 on Reader's Service Card.

CHROMIUM-COPPER: MECHANICAL, ELECTRICAL, AND THERMAL PROPERTIES

Table 1. Chemical Specifications of MIL-C-19311 (Two Compositions); Balance, Copper.

Element	Composition I, %	Composition II, %
Zn	≤0.70	
Fe	≤0.15	
Si	≤0.10	
Li	≤0.05	
P	≤0.05	≤0.04
As	≤0.005	
Ca	≤0.005	
Ag		0.08-0.12
Pb		≤0.015
Cr	0.40-1.30	0.40-1.00
Other	≤0.05	≤0.15

A commercial 3.75-in.-diam bar of this precipitation-hardening material (Mallory-3; 0.53% Cr) would not show consistently the yield strength required by MIL-C-19311, Composition 1 (Tables 1 and 2). The supplier's tests indicated yield strength ranging between 35,000 and 44,000 lb/in^2 in the solution-annealed and age-hardened condition.

Reheating to 1825°F for 0.5 hour, water quenching, and aging for 2.5 hours at 930°F increased the strength, hardness, and electrical conductivity (Table 2). However, the indication is that during heat treatment at the mill the mass of the 3.75-in.-diam bar had slowed the cooling rate at its center, so that complete response to subsequent age hardening was impossible.

It is recommended that for certain applications the requirements of MIL-C-19311, Composition 1, be relaxed as indicated in Table 2.

After simulation of augmented-spark-injector (ASI) furnace brazing at between 1800° and 1900°F, chromium-copper responds to a degree to age hardening; the average cooling rate between 1925° and 800°F was 14.7°/min. After brazing, the average yield strength (0.2% offset) of specimens cut from a 3-in.-diam bar was 17,200 lb/in^2 (Table 3); after brazing followed by 3-hour aging at 930°F, it was 29,200 lb/in^2. After brazing, the electrical conductivity was 50% IACS; after further aging, it was 81% IACS. The material is not embrittled by hydrogen at high temperatures.

Incorporation of the aging treatment in the ASI brazing cycle decreases the tensile strength at 70°F, but cooling to 70°F, after the brazing and before the aging at 930°F, improves the mechanical properties. The results of further tests of a different heat of Mallory-3 confirm the reported data.

After subjection to simulated ASI brazing, cooling, and subsequent 3-hour aging at 930°F, chromium-copper at 70°F has 80% of the thermal conductivity of OFHC copper. With increase in temperature above 400°F, its thermal conductivity decreases rapidly until, at 840°F, it is 113 Btu ft^{-1} hr^{-1} °F^{-1} (Table 4).

Source: E. F. Schmidt and E. F. Green of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-18865, 18866, 18868, 18755)

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Table 2. Mechanical Properties Specified for Annealed and Aged Chromium-Copper, Test Results Before and After Reheating, and Relaxation Recommended

Form	Cr content, %	Tensile Strength, 1000 lb/in^2: Yield, Offset, % 0.2	Yield, Offset, % 0.5	Yield 0.5%	Ultimate	Elongation in four diams, %	Hardness, Rockwell-B	Elec. condy., IACS, %
			MIL-C-19311					
2.5-3.75 in. bar	0.4-1.0			≥50	≥55	≥10	≥65	≥75
Forging	0.4-1.0			≥40	≥50	≥10	≥60	≥75
			Specimen before reheating					
3.75-in. bar	0.53	34.4	35.5	35.1	54	31	60	87
			Specimen after reheating					
3.75-in. bar	0.53	40.9	42.8	41.5	56.1	28	66	94
			Relaxation recommended					
				≥30	≥40		≥50	

Table 3. Average Mechanical Properties of Chromium-Copper Brazing at 1800° to 1900°F; Four Conditions plus OFHC Copper

Condition	Tensile strength, 1000 lb/in² Yield, 0.2% offset	Tensile strength, 1000 lb/in² Ultimate	Elongation in four diams, %	Elec. condy., % IACS	Hardness, Rockwell-F
A	17.2	34.1	42	50	60
B	29.2	43.7	33	81	85
C	14.6	33.1	47	50	60
D	28.7	43.1	35	81	85
E(OFHC Cu)	5.5	29.2	42	101	

Conditions: A, 20 min at 1925°F under argon; furnace cooling to 800°F in 76 min.
B, A plus 3 hours at 930°F.
C, 20 min at 1925°F under hydrogen; furnace cooling to 800°F in 76 min.
D, C plus 3 hours at 930°F.
E, brazing followed by cooling to 1200°F in 252 min.

Table 4. Thermal Conductivities after Brazing of OFHC Copper and Subsequently Aged Chromium-Copper

Av. temp., °F	Thermal conductivities of coppers, Btu ft^{-1} hr^{-1} $°F^{-1}$ OFHC[a]	Chromium	Chromium:OFHC, %
103	232	183	79
103	232	175	75
103	232	179	77
189	228	172	75
323	223	174	78
395	220.5	175	79
530	218	166	76
505	218.5	159	73
756	210	118	56
840	208	113.5	54

[a]From *Handbook of Thermal Physical Properties of Solid Materials*. Vol. 1, 1961.

MINIMUM MECHANICAL PROPERTIES OF OFHC COPPER AT HIGH TEMPERATURES

Presented in tables and graphs are the mechanical properties of oxygen-free, high-conductivity (OFHC) copper at temperatures between 70° and 1400°F. Tensile bars machined from plate stock were first annealed for 10 min at 925°F under argon. Half of the bars were then tested in the fine-grained condition; the other half were first subjected to a furnace-brazing cycle that left them coarse grained. Tensile testing was at a strain rate of 0.005 in. in^{-1} min^{-1} beyond yield.

The annealing did not result in maximum softening of the bars, so that those tested at 70°

and 900°F show higher yield and ultimate strengths than should be true for properly annealed OFHC copper. The testing at temperatures higher than 900°F was not affected by the annealing; deviations in the data for such temperatures result from difficulties in measurement.

Source: S. D. Foster of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18583)

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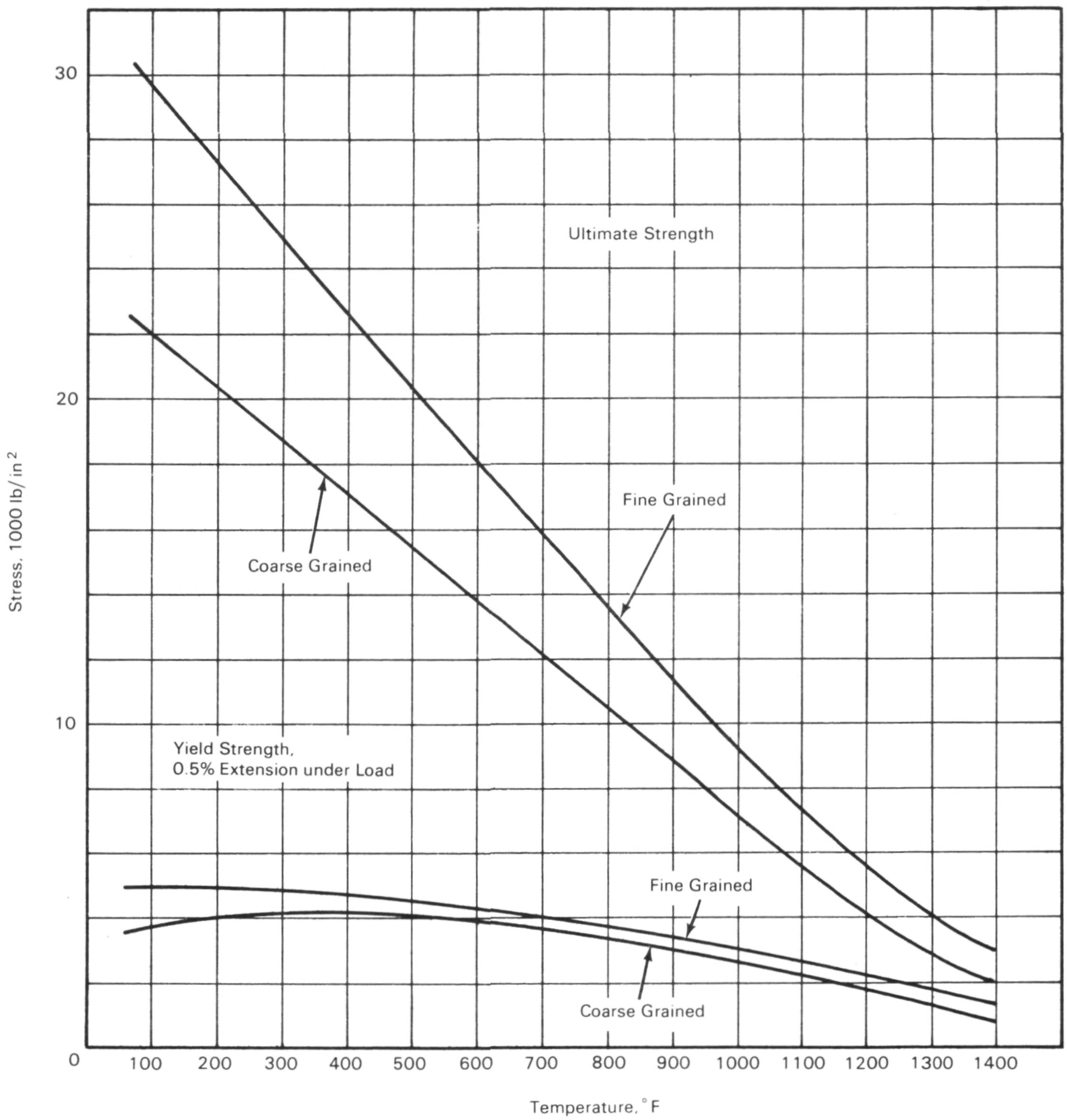
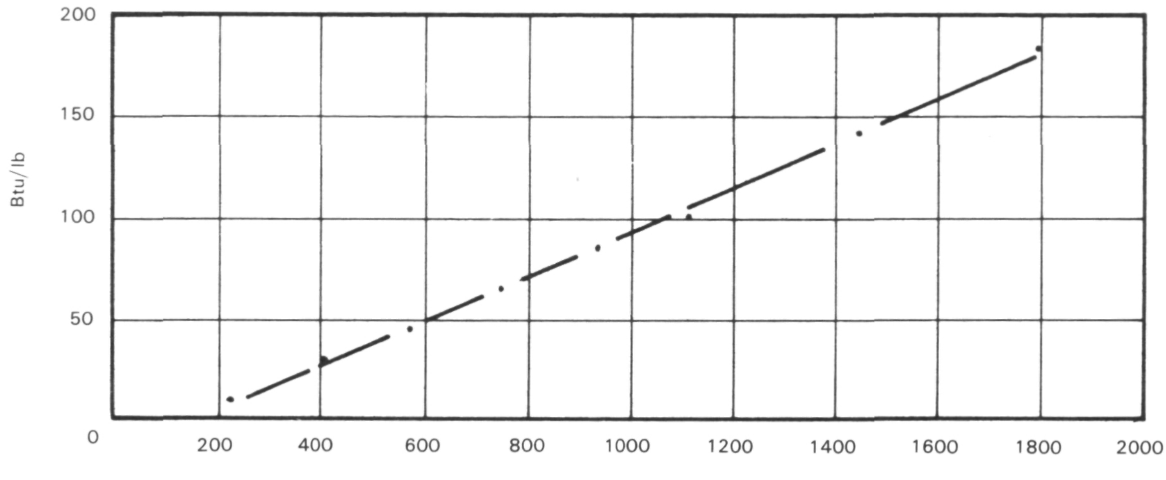


Minimum Mechanical Properties of OFHC Copper between 70° and 1400° F



Specific Heat of OFHC Copper

THERMAL CONDUCTIVITIES OF NINE BRAZING ALLOYS BETWEEN −300° AND +800°F

Thermal conductivities at temperatures between −300° and +800°F are reported (see Table) for nine common brazing alloys based on gold, silver, copper, or manganese. The samples were machined from castings from remelts under brazing conditions. The data are true for the brazing alloys only, since no account was taken of possible reactions with metals being brazed; they serve for comparison of the alloys alone, and cannot be used for calculation of the performance of a joint in service.

Source: G. Huschke, Jr., and E. R. Roeder of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-18632)

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Average Thermal Conductivities of Nine Alloys

Mean Temp., °F	Conductivity, Btu/hr-ft^2(°F/ft)
RBO-170-045, 75 Ag-20 Pd-5 Mn	
-300	16.0
- 96	40.4
- 50	40.3
106	43.9
252	47.9
420	60.5
654	69.2
836	75.1

(continued)

Average Thermal Conductivities of Nine Alloys (Cont'd)

Mean Temp., °F	Conductivity, Btu/hr-ft^2(°F/ft)
RBO-170-062, 90 Ag-10 Pd	
-299	40.7
-201	40.9
- 92	47.0
101	87.0
305	109.2
502	115.5
800	135.2
LBO-170-105[a], 92.5 Ag-7.5 Cu	
-306.5	53.7
-108	135.5
- 49	146.1
101	155.0
250	158.8
400	160.5
654	169.1
803	173.1
Rocketdyne experimental, 90 Ag-5 Pd-5 Cu	
-299.4	58.0
- 97.2	66.6
- 52.2	76.3
118.0	99.1
252.0	104.4
399.0	117.6
648.7	128.4
801.1	133.9
RBO-170-077, 13.5-15 Zn-1.0 Cu-0.75 Ni; bal. Ag	
-295.0	17.4
- 96.0	26.7
- 50.0	32.7
101.7	43.7
252.0	54.6
402.3	63.8
652.5	69.8
798.0	71.6
RBO-170-064, 82 Au-18 Ni	
-290	5.4
-198	7.6
- 97	8.9
102	14.2
302	19.5
501	22.3
806	26.3

(continued)

Average Thermal Conductivities of Nine Alloys (Cont'd)

Mean Temp., °F	Conductivity, Btu/hr-ft^2(°F/ft)
	RBO-170-089, 25 Ag-50 Au-22 Cu-3 Zn
-298	12.9
-100	23.6
- 50.8	22.2
102	27.8
250	35.6
401	45.0
656	58.8
802	64.3
	RBO-170-065, 62 Cu-35 Au-3 Ni
-300	8.3
-198.6	14.5
- 80	21.1
103	26.7
300.8	36.8
545.9	43.5
815.2	50.6
	AMS-4780, 67 Mn-16 Co-16 Ni-1 B
-283.3	4.53
-198	6.90
-102	6.94
100	8.69
298.5	8.49
504	7.50
797	8.14

[a]For 0.2% Li modification

Section 3. Improvements in Processing

HIGH-TEMPERATURE PROTECTIVE COATINGS FOR REFRACTORY METALS

Ten tungsten, ten molybdenum, and six niobium specimens have been coated with iridium by electrodeposition from a fused-salt electrolyte (70 sodium cyanide–30 potassium cyanide by weight). Acid testing and visual examination show that all coatings are dense and coherent.

An earlier electrolytic cell was modified in two ways (Fig. 1): an inert-gas chamber was juxtaposed to, but separated from, the fused-salt chamber by a gate valve to allow admission of the refractory metal to the electrolyte without admission of air; and the earlier crucible of alumina was

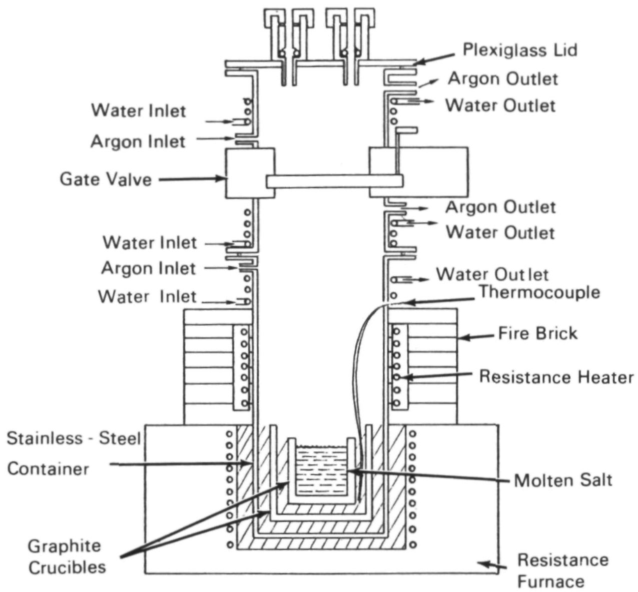


Figure 1. Fused-Salt Cell

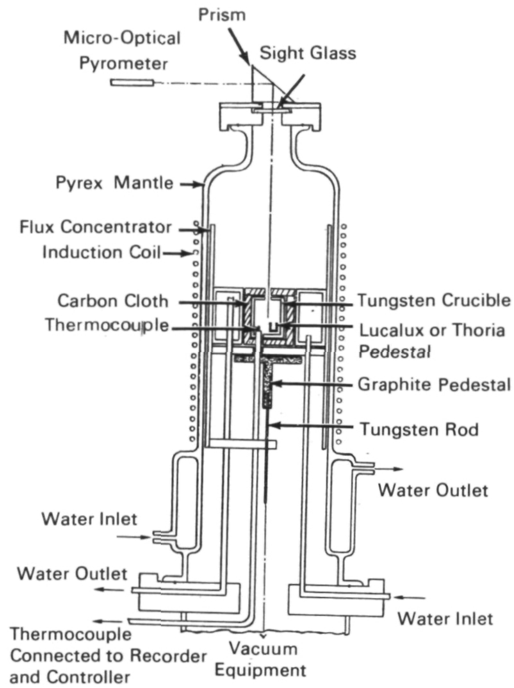


Figure 2. Diffusion-Annealing System

replaced by one of graphite to eliminate contamination due to the presence of aluminum oxide.

An automatic, controlled-temperature, induction-heated, diffusion-annealing system has been constructed and calibrated for diffusion studies (Fig. 2). Various hot-pressed tungsten-iridium diffusion couples have been annealed at 1300°, 1530°, 1710°, 1900°, and 2125°C. The sectioned specimens are being examined metallographically.

Source: J. Rexer and J. M. Criscione of
Union Carbide Corp.
under contract to
NASA Headquarters
(HQN-10079)

Circle 22 on Reader's Service Card.

WELDING, BRAZING, AND SOLDERING HANDBOOK

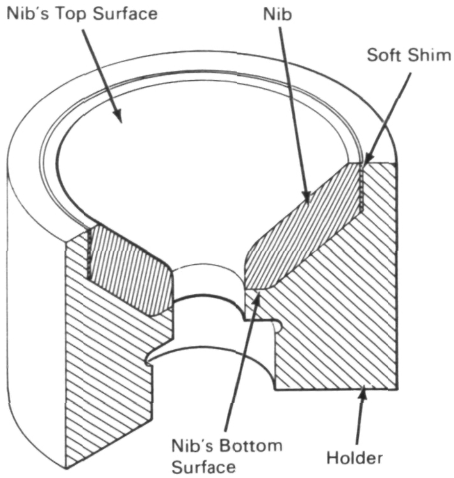
A newly compiled handbook provides design engineers with a single, comprehensive source of information on the selection and application of welding, brazing, and soldering techniques for the joining of various metals. Included are 106 illustrations and tables as well as a short bibliography (52 citations). Summarily described are the joining processes, and criteria for the selection of particular processes for various alloys, types of joint, structural configurations, and thicknesses of material; the advantages and disadvantages of the various methods of joining, for different structural designs and applications, are explained in detail.

The following processes are covered: fusion welding (by arc, electron beam, electroslag techniques, and laser beam), resistance welding, solid-state welding, brazing (filler-metal compositions and properties are described), and soldering (with compositions and properties of solders).

Source: M. L. Koehler *et al* of
The Boeing Company
under contract to
Marshall Space Flight Center
(MFS-20504)

Circle 23 on Reader's Service Card.

DIE INSERTS FOR EXTRUSION OF REFRACTORY METALS



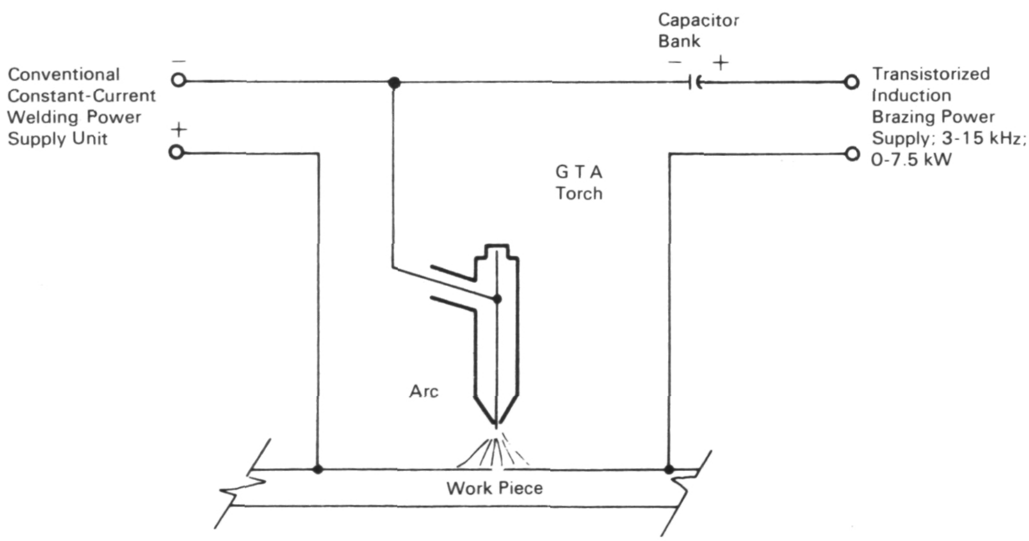
The nib (insert) of improved long-lived extrusion die for refractory metals is held in a steel holder that is relatively easy and inexpensive to machine.

The conical top and bottom surfaces of the refractory nib (typically of an oxide of aluminum, zirconium, or hafnium) must be parallel to ensure favorable stress distribution in the direction of extrusion. For favorable stress distribution in the tangential direction during extrusion, the nib must be stressed in compression by shrinkage of the holder over it. The degree of shrink fitting should be controllable during extrusion, for accommodation of dimensional changes in the die body due to temperature variations; accommodation is provided by a soft metal shim placed between nib and holder. The shim must have a high coefficient of expansion and relatively low strength—like copper.

Source: C. A. Gyorgak and R. J. Hoover
Lewis Research Center
(LEW-10514)

Circle 24 on Reader's Service Card.

CLOSE GENERATION OF SONIC POWER MAY IMPROVE WELDS: A CONCEPT



Although its effects have not yet been evaluated in practice, it is probable that generation of intense sonic power in a weld zone, close to the puddle, reduces the weld's porosity and refines the grain. The principle may be extensible to the molding of metals and plastics also. Newly developed equipment (see fig.), already shown to be an effective source of sonic and ultrasonic energy, may well be successful.

The dc welding current and voltage (with corresponding length of arc) accord with conventional practice. The ac power supply is used to feed, through the blocking capacitor bank, an alternating current that is superimposed on the

direct current so that the power supplied to the weld zone is the sum of the dc power and the root-mean-square ac power.

The ac induction brazing power supply, basically a constant-potential unit, is modified for simulation of a drooping characteristic by use of long cables for deliberate addition of resistance to that circuit. The ac unit consists of a free-running, variable-frequency oscillator, whose frequency is independent of the load constants, driving a power amplifier having a series-resonant output that is tunable for achievement of a unity power factor.

In a test with a frequency of about 4 kHz and a basic dc voltage of 12 V, 115 db was measured 5 feet from the torch; close to the weld the level of sound was intolerable.

In addition to the possible uses mentioned, the system may serve as a basic power supply for in-process ultrasonic testing, or generation of sonic and ultrasonic energy for tests such as destructive tests.

Source: W. M. McCampbell
Marshall Space Flight Center
(MFS-20339)

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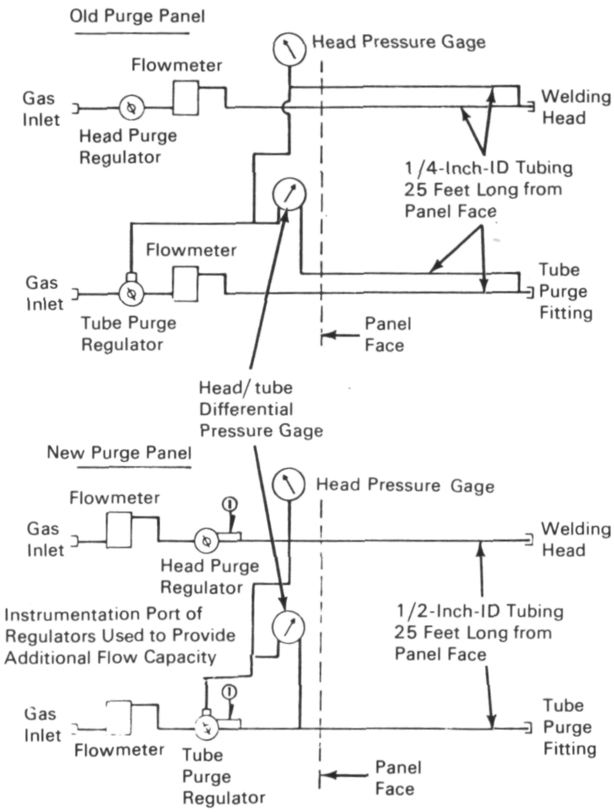
PRESSURE-CONTROL PURGE PANEL FOR AUTOMATIC BUTT WELDING



A conventional pressure-control purge panel can be modified for use in automatic butt welding instead of burn-through welds. The conventional panel (see fig.) was designed for burn-through welds of sleeve-tube combinations; when it is used for automatic butt welding, the difference in pressure between head and tube must be maintained manually. Factors affecting butt welding, such as fit-up, end gap, and preparation of the ends of the tubes, do not apply to sleeve-type welds.

A new modification of the purge panel (see fig.) reduces the drop in pressure between the regulators and the weld head and tube-purge fitting. The regulators now sense very small changes in pressure (as low as 0.1 in. of water) and can maintain automatically the preset difference in pressure between tube and head.

The more stable and constant purge flow under all conditions results in elimination of manual control and in better welds. The invention may interest those concerned with air-regulators for plants and regulating circuits for pneumatic valves, as well as operators of automatic welding machines.

Source: E. J. Lang and B. H. Van Wagner of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18465)

Circle 26 on Reader's Service Card.

IMPROVED NICKEL PLATING OF INCONEL X-750

By a novel technique, Inconel X-750 tubing can be plated with nickel to serve as a wetting agent during brazing. Previous platings were caused to blister and flake by constituents (such as Co, Ti, and Cr) of the alloy and the heat of brazing ($\geq$2050°F).

The new electroplating technique includes acid pickling that leaves a clean surface free from the usual smut resulting from the heat-treated condition, activation that is used for a noncontinuous operation, and a low-stress nickel-plating bath containing none of the organic wetting agents that cause the nickel to blister at high temperatures.

The tubing is degreased before alkaline cleaning, with brushing, for not less than 1.5 min at from 180° to 210°F; it is then rinsed. The pickling bath contains 15 to 20% of nitric acid and 3 to 5% of hydrofluoric acid (both by volume), the balance being water. The bath lasts no longer than 20 min at no more than 120°F before rinsing.

Activation takes from 30 to 60 sec at 70°F in an aqueous solution of (both by volume) 1 to 1.5% nitric acid (42°Be) and 1 to 1.5% hydrofluoric acid (45 to 60% by weight). A nickel strike is made at 70°F in an aqueous solution of nickel chloride at 30 oz/gal and hydrochloric acid at 4.8 oz/gal; the process lasts from 1.5 to 2 min with a current density of 50 A/ft^2.

The tubing is then plated to the required thickness in one of two aqueous solutions. The first, at from 115° to 140°F and pH 1.5 to 2.5 (electrometric), contains nickel sulfate at 44 oz/gal, both nickel chloride and boric acid at 5 oz/gal, and 30% hydrogen peroxide at 0.057 oz/gal daily. The pH, which tends to rise, is lowered with sulfuric acid or raised with nickel carbonate. The current density is from 25 to 100 A/ft^2.

The alternative plating solution at 100° to 140°F contains nickel sulfamate at 60 oz/gal, boric acid at 4.5 to 6 oz/gal, and 30% hydrogen peroxide at 0.057 oz/gal; the pH is maintained between 3 and 4 (electrometric) with either sulfamic acid or nickel carbonate, and the solution is filtered continuously. The current density is from 40 to 80 A/ft^2. The plating must be smooth and continuous, with no discoloration indicative of burning.

Stripping of faulty platings and replating are described.

Source: C. A. Kuster, J. E. Feeney, and M. E. Farmer of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-18604)

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CORROSION PROTECTION OF ALUMINUM ALLOYS IN CONTACT WITH OTHER METALS

Aluminum alloys used in equipment exposed to corrosive environments are commonly protected by various coatings. The more protective coatings are effected by anodizing (chromic or sulfuric acid treatment) or alodizing (chromate treatment) of the aluminum. For certain structures, anodized or alodized aluminum alloys may be used in contact with 347-CRES (corrosion-resistant stainless steel) or 6 Al–4 V titanium alloy. In such instances, galvanic corrosion may result from electrochemical coupling between the dissimilar metals when the surface coatings are insufficiently protective or break down in corrosive atmospheres.

The quality of chemical and galvanic protection afforded by anodized or alodized coatings applied to test panels of various aluminum alloys was therefore investigated. The panels were placed in firm contact with panels of 347-CRES and 6 Al–4 V titanium alloy. All pairs of panels were subjected to the standard ASTM salt-spray test for various periods before visual examination for corrosion.

Sulfuric acid–anodized coatings provided the best protection. When properly applied, both anodic coatings (sulfuric acid and chromic acid treatments) were impervious to the salt spray. Since these coatings are also poor electrical conductors, they prevented formation of galvanic couples between the aluminum alloy and the other metals.

When the anodized or alodized coatings broke

down under the salt spray, the degree of galvanic corrosion varied with the difference in electrochemical potential between the aluminum and the paired metal.

Alodized (chromate) coatings, although capable of protecting aluminum alloys not in contact with more-anodic metals, did not prevent galvanic attack of the coated aluminum coupled with either of the two metals. This lack of protection is due to the fact that the chromate coating is a relatively good electrical conductor and thus permits electrochemical coupling of the dissimilar metals in the presence of salt spray (or other electrolyte).

Source: C. A. Kuster of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18526)

Circle 28 on Reader's Service Card.

RENEWAL OF CORROSION PROTECTION OF COATED ALUMINUM AFTER WELDING

Frequently it is necessary to weld or otherwise apply heat to aluminum alloys that have been previously protected with conversion coatings against atmospheric corrosion during fabrication and assembly. Comprehensive tests have disclosed that temperatures exceeding 140°F (60°C) seriously and permanently reduce the protection afforded by such coatings; tested were both welds and laboratory heat treatments of samples of 2219-T87 alloy (aluminum-copper) as thick as 1 in.; the conversion coatings, with either Iridite 14-2 or Alodine 1200, were either fresh or aged as long as 2 months.

Since a weld commonly results in temperatures as high as 140°F as far as 6 in. from the site, the damaged coating should be stripped manually from the area within at least 6 in. of the weld. Then this area should be recoated by sponge or spray with the original solution. When the strength of the recoating solution is two or three times that of the original bath, the protection afforded by the recoating equals or exceeds the original protection.

Moreover, touch-up treatment by spray, with a conventional solution, improves the protection by aged or abraded coatings. Fully completed tank assemblies should be touched-up by spray for ensurance of adequate protection.

Source: R. H. Higgins
Marshall Space Flight Center
(MFS-20361)

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COATINGS DECREASE METAL FAILURE FROM FATIGUE

Metals under cyclic stress have a greater tendency to fail in the atmosphere than in vacuum. This tendency is attributed to reaction of atmospheric oxygen and water vapor, or other reactive gases, with the fresh metal surfaces that are exposed by fatigue cracking. Thus, if the atmosphere's contact with metal in fresh cracks could be limited or prevented, the fatigue properties measured in air should approach those observed in vacuum; testing of metals for spacecraft would be simplified, and the service life of parts subject to fatigue failure in reactive environments could be increased by suitable protective coatings.

Preliminary experiments were performed with specimens of pure magnesium, in flat, localized-stress, cantilever configurations, that had been abraded mechanically and then polished chemically. Fatigue tests consisted of cyclic, fully-reversed plane bending (30 cps) under constant load at room temperature. The first tests were performed to establish curves for fatigue life versus cyclic loading in air at 1 atm and in vacuum at 10^{-7} Torr. Coating materials were then selected on the premise that they would be (1) relatively resistant to penetration of reactive gases in the atmosphere over the period of test, and (2)

sufficiently ductile to withstand, without fracture, straining of the metal substrate by bending.

Fatigue tests in the atmosphere were conducted with base metals such as magnesium, magnesium-thorium alloy, magnesium-lithium alloy, and aluminum alloys 1100, 2024, 6061, and 7075; applied coatings included polymeric types such as silicone, polyamide, polyethyleneterephthalate, and epoxy, as well as electroplated nickel.

In every instance, test data indicated that the fatigue life of coated specimens in air exceeded that of uncoated specimens; in some instances it equaled the life in vacuum. Fatigue strengths of coated specimens in air were increased by 20 to 55%.

Metallic, inorganic, or polymeric coatings, selected for special optical, electrical, or mechanical properties, also may be used if they meet the basic impermeability and ductility requirements. They may be applied by established techniques, such as electroplating, solvent or aqueous sprays, dipping, brushing, or vapor deposition.

Because polymeric materials are usually quite permeable to oxygen, for long-term protection they must be specially evaluated beforehand.

Source: H. T. Sumsion
Ames Research Center
(ARC-10015)

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ADVANCES IN ALUMINUM ANODIZING

Aluminum alloys 2014, 2219, and 7006 were considered in the development of techniques for white anodizing. A coating for aluminum was sought that would equal white enamel in surface reflectance, be highly resistant to corrosion, and weigh less than earlier coatings.

A method of mechanical and chemical pretreatment of the aluminum surface was developed to effect a surface reflectance of from 82 to 86%. The treatment consists in cleaning, chemical etching, abrasive blasting with aluminum oxide, cleaning, alkaline etching, acid deoxidizing, fluoride etching, and acid deoxidizing.

The most successful anodizing process had an electrolyte of 26% sulfuric acid containing glycerol, lactic acid, and titanium ammonium lactate. While thin films (between 0.00010 and 0.00012 in.) from this electrolyte gave absolute reflectance values of between 70 and 80%, they could not withstand 1000 hr of salt spray without corrosion. Although film thicknesses between 0.0008 and 0.0010 in. resisted the corrosion, their absolute reflectance ranged between 45 and 55% only.

The best pigmentation resulted from induced precipitation of lead sulfate from a complexed acetate solution with soluble salts of barium, strontium, or calcium. The lead sulfate is dissolved in an acetic acid solution of ammonium acetate. When the anodic film, containing a soluble barium ion such as the acetate, is immersed, a dense and fine precipitate is formed. The precipitation proceeds slowly but steadily and impregnates deeply.

The anodic film's resistance to corrosion is increased by secondary sealing in a polyorganosiloxane after primary sealing in boiling water. The polyorganosiloxane provides such a good paint base that, even after 1250 hr of salt spray, the surface can be painted with NASA's white enamel with excellent results.

Another sealant, based on a benzyl alcohol solution of fluorochemical surfactants and carboxylic acids, gave excellent resistance to salt spray. Neither this sealant nor the polyorganosiloxane was affected by welding, beyond 1 in. from the bead's center. Both these sealants, especially the siloxane, materially increased the dielectric-breakdown voltage of the anodic film.

Source: K. H. Dale of
Reynolds Metals Co.
under contract to
Marshall Space Flight Center
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NASA-Langley, 1971